A MODEL TO MEASURE SUPINATION AND PRONATION OF THE FOOT OVER DIFFERENT LEVELS OF PHYSIOLOGICAL STRESS USING AN IN-SHOE MONITORING SYSTEM

S. M. Haddock, M. D. Tremaine, J. Albrigo, G. Branche, K. C. Teed

Anderson Orthopaedic Research Institute
Alexandria, Virginia, USA

INTRODUCTION

Pronation and supination are inherent factors of gait. The alignment of the segment system's inclusive joints, the rotation of the same system, as well as various pathologies can all yield natural motion about the foot's anteroposterior axis. Compensatory or overpronation, however, is thought to cause a number of problems, including lateral compression syndrome of the knee, illiotibial band syndrome (Leach, 1982), Achilles tendinitis, posterior tibial tendinitis (Clancy, 1982), medial tibial stress syndrome, and plantar fasciitis (McKenzie et al., 1985). Considering the great influence of such motion towards running injuries, the implementation of a model for its detection is needed. The chosen model focuses on foot regions of orthopaedic importance to pronation and supination. This study utilized an in-shoe force measurement system that identifies timing patterns, magnitude of force, and pressure distribution within the shoe. Not only was the study to assess the model, but the measurement system as well. Finally, the study examined pronation and supination under several different levels of perceived exertion. Resultant timing and force patterns may predict the need for changes in training, shoe type, and possibly orthotic attention.

METHODOLOGY

The subject sample consisted of five male recreational runners. All subjects were recruited for the study, and an informed consent was signed. The materials utilized in this study were: a) Tekscan software; b) a 486 DOS computer with mouse support; c) computer cuff data links; d) a calibrated PreCor treadmill; e) a standardized walkway; f) a Borg Rating of Perceived Exertion (RPE) chart; and g) New Balance 495 running (athletic) shoes. The measurement technique employed in this study used an in-shoe force monitoring system known as Fscan. The Fscan system utilizes a foot sensor that contains 960 individual sensors that retain capacitive transducer technology to gather force and timing data. These foot sensors can be customized to the individual needs and sizing of each subject. To control for shoe to shoe variability, all subjects were fitted and ran in the same brand of athletic shoes.

Each subject was tested under six different conditions. These conditions include the following: 1) walking under normal gait conditions along walkway; 2) jogging at fifty percent of maximum along the same walkway; 3) walking at three miles per hour on treadmill; 4) running at light intensity on treadmill; 5) moderate running on the treadmill; and 6) hard running on the treadmill. The intensity for the last three conditions was determined using the RPE scale as well as self-reported data throughout the testing procedures. The RPE scale is color coded for ease of use and explanation (blue for light values 6 to 11; green for moderate values 12 to 16; red for hard values 17 to 20).

After a period of acclimatization on the treadmill, the subjects were weighed and fitted for a pair of New Balance 495 athletic shoes. The subject was first asked to walk down a standardized walkway at normal gait conditions. Then, the subject was asked to jog down the same walkway at fifty percent of their maximum running intensity. This was then followed by the treadmill conditions, beginning with walking at three miles per hour. Before proceeding further, the subject was stopped and asked training information as to what pace would be a comfortable training run, and all were given an explanation of the RPE scale. The subject was then returned to the treadmill for the final three testing conditions. Based upon self-reported data, the subject was instructed to run at a moderate pace and asked to respond to the RPE scale every minute throughout the testing. When the subject reported values in the center of the light section of the RPE scale, a measurement was recorded via the foot sensors. Two measurements were taken at each stage. Velocity was increased one-half mile per hour every two minutes. Recordings were taken at the subject's velocity for a medium distance race (between moderate RPE values of 12 to 16), and at a hard running velocity, or RPE values between 17 to 20.

RESULTS

The peak force values for the walking treadmill condition elicited the lowest values across all conditions. This would suggest a marked decrease in peak vertical ground reaction forces acting upon the foot and segment system while on a treadmill as opposed to a hard, inelastic surface such as concrete or pavement. Also, the forces for the walkway jog and the treadmill light running were very similar, suggesting that comparisons between treadmill and over the ground conditions are feasible and accurate.

There were significant bilateral differences from the moderate to hard running conditions. The left foot showed decreased forces in the heel areas, and increases in the arch, metatarsal, and toe regions. An increase in midfoot pressure centering suggests an anterior movement of center of pressure. Also, the medial force increases of the forefoot and toe areas are greater than those on the lateral side, possibly a result of increased pronation in the forefoot and toe regions. The right foot, however, exhibited either negligible change or marked increases in all areas of the foot. Larger medial force increases compared to negligible lateral force changes suggest an increase in pronation with increased perceived exertion. For both feet, the first metatarsal area showed large force increases.

Integral data again showed bilateral differences. Left foot data showed slightly higher medial values for conditions of treadmill walking and the moderate run. The other four conditions show higher lateral integrals, though the difference between the medial and lateral sides is quite small. This fails to represent any significant trend, although it suggests the foot can exhibit higher forces on either side of the foot over a variety of exertion levels. The right foot has higher medial integrals over all conditions except the hallway walking, with the greatest differences in the light, moderate, and hard running conditions. This shows a trend that complements the force data insomuch to state that there appears to be a trend for increased pronation in the higher perceived exertion levels. Integral data for the treadmill conditions was higher than for comparable walkway conditions. Though the peak vertical ground reaction forces are lower on the treadmill, the force over time is greater, suggesting greater loading periods in treadmill gait.

The timing data produced some interesting results. The time to peak of the lateral arch always occurred before that of the medial arch. The same was true of the time to peak of the fifth metatarsal as compared to the first metatarsal. The time gap between the lateral and medial arch and the fifth and first metatarsal decreased as the perceived exertion levels increased, suggesting the decrease in gait cycle is accompanied with increased pronation. Strangely though, the timing of the light run condition on the right foot was exaggerated. The time to peak of the lateral arch and fifth metatarsal occurred before the medial arch and first metatarsal, respectively. However, there was a marked increase in the time between the time to peak of the lateral to medial regions. The time to peak of the medial and lateral toes of the left foot is very similar. The same is evident on the right foot data as well.

CONCLUSIONS

Based on the results of the study, the following conclusions are warranted:

1) Variance is high, even between successive steps.
2) Treadmill walking produces the least amount of vertical ground reaction forces across all conditions.
3) Treadmill conditions produce greater integrals than walkway conditions.
4) Significant bilateral differences were found between moderate to hard running conditions.

REFERENCES

Clancy, W. G. (1982). Tendonitis and plantar fasciitis in runners. In Prevention and treatment of running injuries. R. D'Ambrosia, D. Drez (eds.). pp. 77-87. New Jersey: Slade.

Leach, R. (1982). Running injuries of the knee. In Prevention and treatment of running injuries. R. D'Ambrosia, D. Drez (eds.). pp. 55-75. New Jersey: Slade.

McKenzie, D. C., Clement, D. B., Taunton, J. D. (1985). Running shoes, orthotics and injuries. Sports Med 2:334-337.